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AUTOMOTIVE ENGINEERING LABORATORY

REPORT ON

TX-200 TRANSMISSION
OIL COMPATIBILITY PROGRAM

Report No. DPS-235

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Dates of Test: 31 October 1961 through 23 February 1961

ABSTRACT

For logistic reasons, the military has used engine oil in its relatively few fully automatic transmissions. With the increasing application of new fully automatic transmissions it was considered desirable to study the effects of engine oil on automatic transmissions.

A procedure was developed for laboratory compatibility tests with the TX-200 transmission. Using this procedure a referee base-line condition was established for the TX-200-2X transmission with MIL-L-2104A, OE-10, M14500, REO-148-61 oil. The objectives of the tests covered in this report were to evaluate MIL-O-10295, OE-S arctic engine oil and MIL-L-2104A, OE-30 engine oil as automatic transmission fluids and to compare the results of the laboratory tests with actual cross-country test-course operation. These tests showed that with reference to the established base line, MIL-O-10295, OE-S, REO-127 oil is incompatible. However, the laboratory test cycle is less severe on clutch wear and more severe on low-range gearing than the 5000-mile cross-country test. Thus it is recommended that a 5000-mile cross-country test be run in a cold climate with arctic engine oil as the transmission fluid to determine whether or not low-sun-gear failures could occur during actual field operation. The MIL-L-2104A, OE-30, M14804 oil was compatible with the transmission except for breakdown of the polyacrylate piston seals. Bench-type investigations should be conducted to determine the cause of seal failure.

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1. INTRODUCTION

In the development of automatic transmissions for passenger cars the automotive industry found it necessary to use special oil for a transmission fluid. When automatic transmissions were developed for commercial trucks, the practice of using special oil was carried over. For logistic reasons, the military has used engine oil in its large semiautomatic transmissions and in its relatively few, smaller, fully automatic transmissions. With the increasing application of new fully automatic transmissions it was considered desirable to study the effects of engine oil on automatic transmissions.

A test procedure for determining the effects of oils was designed for dynamometer operation of the TX-200-1 transmission. This procedure was intended to include typical field operations while maintaining a severity level high enough to obtain results in 240 hours of operation.

A 240-hour test of a TX-200-1 transmission using MIL-L-2104, OE-10, M-556 oil, was conducted with a GMC-302 engine as the power source (Ref. 1). Upon inspection the transmission was found to be in excellent condition except for some distress on the low sun gear. It was concluded that the severity level was not high enough to yield different results for compatible and incompatible oils. It was recommended that for any following tests full rated transmission input be obtained, that full retarder effects be obtained, and that sump temperature be held between 225°F and 250°F.

Procedures were revised and tests were conducted on two TX-200-2X transmissions with one using MIL-L-2104, OE-10, M-556 oil and the other using MIL-O-10295, OE-S, REO-127 oil (Ref. 2). The power source was a Reo-OV 195 engine which produced at test conditions a maximum brake horsepower of 145 and a maximum torque of 300 ft-lb. The transmissions contained the added clutch plates but the new low-range gearing was not included.

The transmission using MIL-L-2104, OE-10, M-556 oil exhibited some evidence of increased severity when shifting became rough in the last 20 hours and front pump pressures pulsated rapidly. However, on inspection the transmission was found to have a satisfactory appearance except for deposits in the converter section and distress on the low sun gear.

The low-range gearing of the transmission using MIL-O-10295, OE-S, REO-129 oil failed abruptly after 95 hours of operation. There was an indication that the oil contributed to the wear within the transmission. However, the duration of the test was not sufficient to form the basis of an opinion regarding sludge. It was recommended by the CRC Inspection Panel that the test be rerun, extending the operating time by reducing the severity if no modified low-range parts could be obtained.

Three new TX-200-2X transmissions were obtained for tests with OE-30, OE-10, and OE-S oils (Ref. 3). The first test of this series was conducted with MIL-L-2104A, OE-10 oil, Qualification No. M-14500, REO-148-61 to establish a base-line condition. It was decided that although the low sun gear was spalled, the MIL-L-2104A, OE-10, M-14500, REO-148-61 oil was compatible with the TX-200-2X transmission and that a base line had been formed. It was also decided that the condition of this transmission represented the minimum condition which would be acceptable to Ordnance. Thus, MIL-L-2104A, OE-10, M14500, REO-148-61 oil yielded a referee condition.

This report covers the last two tests of the series. Transmission, Serial No. OX181 was run with MIL-O-10295, OE-S, Reference No. REO-127, arctic oil, followed by Transmission, Serial No. OX164 run with MIL-L-2104A, OE-30 oil, Qualification No. M-14804, REO-149-61. The object of these two tests was to evaluate the oils as automatic-transmission fluids.

This report also covers the results of the TX-200-3X transmission, Serial No. 30821 with MIL-L-2104A, OE-10, M-14500, REO-148-61 oil operated for 5000 miles in the M35E8, 2-1/2 ton truck, over the Churchville cross-country test course. The prime object of this test was to evaluate the transmission. The secondary object was to obtain a comparison between laboratory and field data on the referee oil.

2. DESCRIPTION OF MATERIEL

2.1 Transmission

The TX-200 transmission provides fully automatic shifting over the entire operating-speed range and is nearly identical to the commercial version. There is a manual range selection for low, drive, and reverse. Low range permits operation in first converter, first lockup and second lockup. Drive range permits operation in third converter, third lockup, fourth lockup, fifth lockup and sixth lockup. The transmission also has manual positions to hold in fourth and fifth gears. On each shift the transmission momentarily drops into converter.

As shown in Figure 1, the transmission consists of a torque converter, a planetary gear train, and a hydraulic control system for shifting gears. The torque converter, which is coupled directly to the engine, acts as a torque multiplier when a low-speed, high-torque output is needed, and it serves as a fluid coupling when the transmission is shifting gears. When applied, the hydraulic retarder assists the brakes of the vehicle by churning oil and converting rotational energy into heat which is dissipated by the transmission fluid.

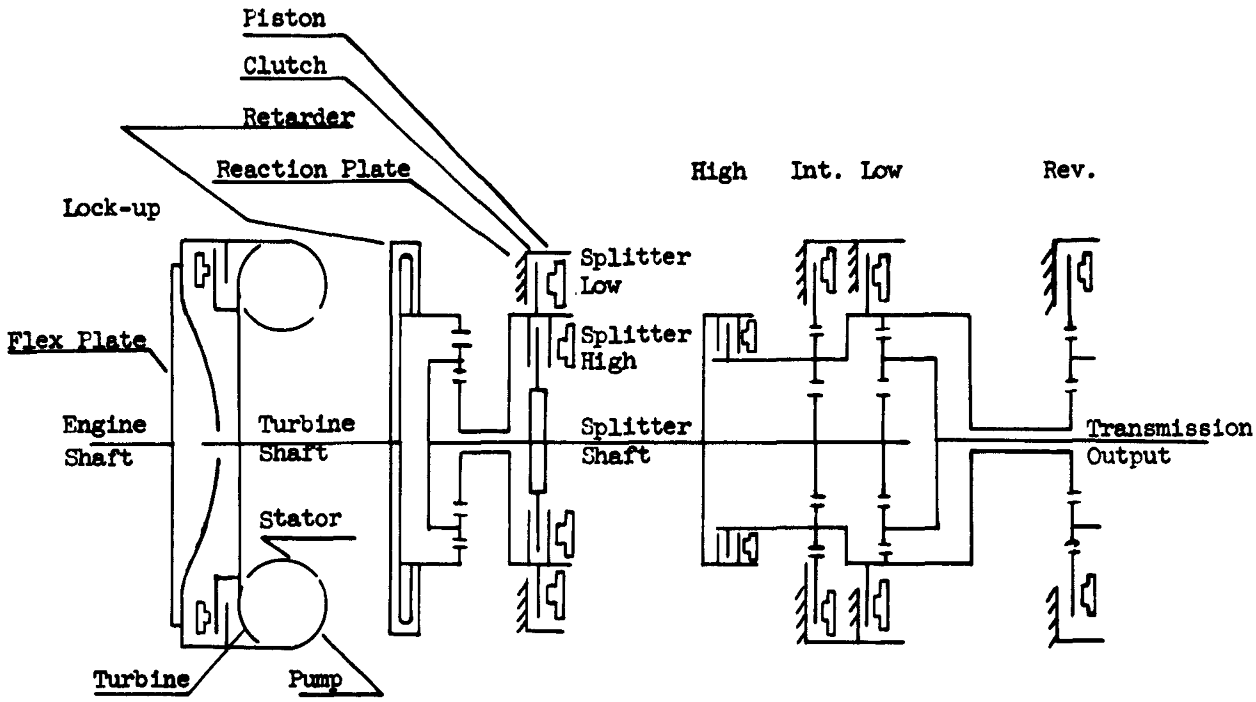


Figure 1: Power Flow in TX-200-2X Transmission.

The basic difference between the TX-200-1 transmission used for the first test (Ref. 1) and the uprated (400 ft-lb, 4000 rpm) TX-200-2X transmission used for later tests (Ref. 2) was the addition of a clutch plate to each range. The TX-200-2X transmission covered in the previous report (Ref. 3) and the two TX-200-2X transmissions covered in this report differed from those previously used as follows:

a. The rear and front housings were aluminum instead of cast iron.

b. New clutch material was used.

c. The reinforced low-range planet carriers were included.

d. The lockup pressure plate had a weep hole.

e. The power-takeoff gear was welded to the high-range clutch housing.

f. The bronze retarder thrust washer was replaced with a needle thrust bearing and steel washer.

g. A three-element converter was used. To match the Model V-549 engine at 400 ft-lb, the converter blading was changed, certain pressure-regulating valves were changed to increase pressure on the clutch plates, and certain orifices were changed to adjust the shift points.

The TX-200-3X transmission which was tested in the vehicle differed from those tested in the laboratory as follows:

a. Oil holes were added to increase oil flow to the intermediate-range clutches.

b. The splitter low clutch-plate tangs were relocated to mate with new grooves on the outer surface of the splitter housing.

c. The valve body was modified to accommodate the lower speed of the LDS-427 engine.

2.2 Transmission Fluid

Specification MIL-O-10295, OE-S oil bearing the Coordinating Research Council (CRC) designation REO-127 is one of the better oils qualifying under this engine oil specification. Specification MIL-L-2104A, OE-30 oil, Qualification Number M-14804; REO-149-61 is slightly lower in quality than the present referee-grade engine oil. Analyses of these oils are presented on Table V, along with the properties of MIL-L-2104A, OE-10, Qualification No. M-14500, REO-148-61 oil.

3. DETAILS OF TEST

3.1 Procedure

The test cycle (Table I) and operating conditions were the same as for the previous test (Ref. 3). As on all tests of this type the new transmission was initially disassembled, inspected, and rebuilt. As on the previous test, a model V-549 engine rated at a maximum torque of 480 ft-lb at 2000 rpm was used as the power source. To match this engine with the transmission rated at 400 ft-lb maximum input torque, the engine had to be operated at part throttle. During the first test with this engine the throttle position was adjusted to reproduce the intake-manifold vacuum readings which yielded 400 ft-lb torque at the given speed during the initial part-throttle, constant-torque power check. At test conditions the engine produced a maximum of 196 horsepower. During the course of the test the actual values of input torque fluctuated due to changes in atmospheric conditions and decreased by 12% during the course of the test due to changes in engine characteristics. Thus, to maintain test uniformity in the following two tests, it was decided that instead of trying to maintain a fixed transmission input torque, the output torque would be adjusted to duplicate the results of the first test of the series.

Table I. Test Cycle

Time %	Time hr-min	Input (Eng. Cond.) Speed, rpm[a]	Input (Eng. Cond.) Throttle	Output Range	Output Gear	Output Speed, rpm
15	1 - 15	2815	WOT	D	6	2800
20	1 - 30	2620	WOT	D	5[b]	1900
5	0 - 30	2150	VAC 2.6	D	3 Conv	400
20	1 - 30	2450 - 2350	VAC 2.1	D	Shifting[c]	900
					3-4	1200
20	1 - 30	1900	VAC 2.8	D	3	700
5	0 - 30	2150	VAC 2.6	L	1 Conv	200
10	0 - 45	2350 - 2650	VAC 2.1	L	Shifting[c]	450
					1-2	700
2-1/2	0 - 15	600	Idle	N	-	0
2-1/2	0 - 15[d]	0	-	-	-	0

[a]This is for reference only. Conditions are set by output speed.

[b]Retarder applied during this period with engine at WOT. Twenty applications of 30 seconds on and 30 seconds off.

[c]Shifting induced by varying output speed to give one shift every minute to be executed in 5 to 10 seconds. Sixty shifts in drive; 30 shifts in low.

[d]Every three cycles this will be 2 hours instead of 15 minutes.

To measure, absorb, and control the transmission output, two dynamometers, a 1200-hp unit and a 700-hp unit, were coupled end to end with the transmission. This large capacity was required to match the low-speed torque characteristics of the transmissions. The inertial effects of the massive rotors provided the proper acceleration characteristics during shifting cycles. The 1200-hp dynamometer had speed-sensitive servo-controls which had been altered to automatically provide the desired speeds on a fixed-time basis.

During the tests, transmission-oil-sump temperature was maintained between 200°F and 250°F except during converter operation, where the oil-to-cooler temperature was held to a nominal 300°F. The oil temperature was controlled by regulating the water flow through a small oil-to-water heat exchanger.

Operation of the M35E8, 2-1/2 ton truck with the TX-200-3X transmission (Serial Number 30821) consisted of 5000 miles over the Churchville cross-country test course at an average speed of approximately 23 miles per hour. This course is 4 miles long, with grades ranging from 10% to 31.5%, up to 350 feet long. The vehicle carried a

5000-lb payload during the entire test and towed a 6000-lb (gross weight) trailer during the first half of the test. The M35E8, 2-1/2 ton truck is powered by the LDS-427-2 engine, which is a compression-ignition, multifuel engine with an output of 140 horsepower at 2600 rpm.

On completion of the tests the transmissions were disassembled and a transmission inspection was conducted by the Coordinating Research Council Motor Inspection Panel on Automatic Transmissions of the Power Transmission and Power Steering Units and Fluids Group, together with Ordnance personnel. The inspection team examined for wear, sludge, and other indications of deterioration.

3.2 Results

3.2.1 Transmission, Serial Number OX181, MIL-O-10295, OE-S, REO-127 Arctic Oil. The test was started on 31 October 1960 and was stopped due to a failure of the low sun gear on 9 November 1960 after 158 hours of operation. A schedule of test-cycle interruptions is given as Table II.

Upon disassembly, half of the converter section was found to be blued. This probably happened when oil-temperature controls were being adjusted in preparation for the test and a soldered oil line parted due to overheated oil. Operation had to be stopped immediately, causing the lower half of the converter section to be filled with overheated oil which probably blued the components in contact with it.

From the performance curves it is evident that for the (drive, sixth lockup and drive, fifth lockup) ranges requiring full-throttle engine operation, the initial transmission output torque did not come up to the values of the previous test (Ref. 3). The data indicate that the loss was due to a lower transmission efficiency rather than a loss in engine power. The approximate eight per cent lower efficiency may have been due either to greater rubbing friction caused by the thinner oil, or to inherent differences between the two transmissions.

Table II. Schedule of Test Cycle Interruptions, Transmission Serial No. OX181, MIL-O-10295, OE-S, REO-127, Arctic Oil

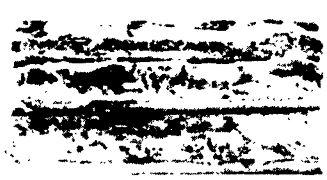
Date, 1960	Test Hours	Remarks	Down Time, hr
31 Oct	0	Start of test.	-
31 Oct	8	Shut down to change plugs and make adjustments to bring up engine power.	5
1 Nov	32	Scheduled 2-hour shutdown.	2
2 Nov	56	Scheduled 2-hour shutdown.	2

Table II (Continued)

Date, 1960	Test Hours	Remarks	Down Time, hr
3 Nov	72	Extended 15-minute shutdown, 1/2 hour at request of construction workers working in the area.	1/2
3 Nov	80	Scheduled 2-hour shutdown.	2
4 Nov	104	Shut down for weekend.	50
7 Nov	128	Scheduled 2-hour shutdown.	2
8 Nov	152	Scheduled 2-hour shutdown.	2
9 Nov	158	Test terminated due to major breakdown.	

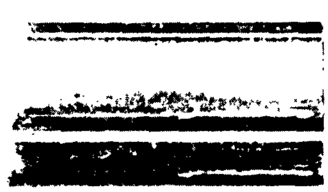
Thirteen quarts of oil were added during the course of the test. This high amount was needed because the oil periodically foamed, built up pressure and spewed out the filler tube. Foaming occurred when during lockup operation the oil temperature to the cooler exceeded 140°F, or when the engine was rapidly brought to an idle. Early in the test foaming occurred during retarder application, but this was eliminated after the oil had been worked for a while and the water flow through the cooler was increased prior to each retarder cycle. On some cycles it was necessary to maintain the temperature of oil going to the cooler at 130°F or lower to prevent the transmission from slipping out of lockup. For a complete summary of temperature data see Table III.

Figure 2 shows the total failure of the low sun gear compared with the pitting and wear pattern obtained on the other tests.

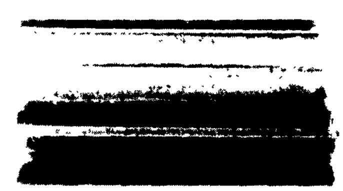


Transmission Serial No. OX181, MIL-0-10295, OE-S, REO-127, Arctic Oil.

Transmission Serial No. OX-178, MIL-L-2104A, OE-10, M-14500, REO-148-61 Oil.



Transmission Serial No. OX164, MIL-0-2104A, OE-30, M-14804, REO-149-61 Oil.



M35E8, 2-1/2 Ton Truck, TX-200-3X Transmission Serial No. 30821 MIL-L-2104A, OE-10, M-14500, REO-148-61 Oil.

Figure 2: Tooth Surface Conditions of the Low Sun Gear.

Table III. Summary of Operating Temperatures

Transmission, Serial Number DX181
MIL-O-10295, OE-S, REO-127 Arctic Oil

Range, -gear	D-6			D-5			D-3 (Conv)			D-3/4			D-3			1-Conv			L-1/-		
Engine speed, rpm	2800			2620			2150			2450 - 2350			1900			2150			2350 - [illegible]50		
Portion of Test: Start - Middle - Finish	S	M	F	S	M	F	S	M	F	S	M	F	S	M	F	S	M	F	S	[illegible]	F
Sump	225	221	237	220	226	219	177	167	204	226	231	227	226	221	228	216	230	230	228	227	241
Converter in.	229	226	231	228	231	226	182	171	211	231	234	226	225	223	229	221	233	234	235	231	238
Oil to cooler.	231	227	231	232	232	228	261	239	239	227	235	227	228	245	230	299	303	292	236	231	238
Oil from cooler.	181	169	119	207	206	156	163	146	96	213	202	161	213	207	179	199	191	126	192	193	157
Retarder out, -avg.				290	301	285															
Retarder out, max.				295	310	295															

Transmission, Serial Number OX164
MIL-L-2104B, OE-30, M14804 Oil

	D-6 S	D-6 M	D-6 F	D-5 S	D-5 M	D-5 F	D-3 (Conv) S	M	F	D-3/4 S	M	F	D-3 S	M	F	1-Conv S	M	F	L-1/- S	[illegible]	F
Sump	216	228	225	228	219	221	180	169	180	226	230	214	232	221	218	214	231	240	229	228	221
Converter in.	172	166	153	179	172	153	156	143	135	179	176	152	181	166	151	180	177	166	184	175	154
Oil to cooler.	220	232	231	231	225	232	262	247	247	228	234	220	231	224	221	267	298	293	232	233	229
Oil from cooler.	209	220	203	223	213	217	169	158	170	212	223	200	222	216	215	194	225	219	218	220	212
Retarder in, avg.				-	244	251															
Retarder out, avg.				-	321	324															
Retarder out, max.				-	329	339															

3.2.2 <u>Transmission Serial Number OX-164; MIL-L-2104A, OE-30, M-14804 Oil</u>. The test was started on 5 December 1960; 240 hours of operation were completed by 21 December. The performance curves illustrate that the transmission output torques were controlled to repeat the data obtained on the OE-10 oil base line test.

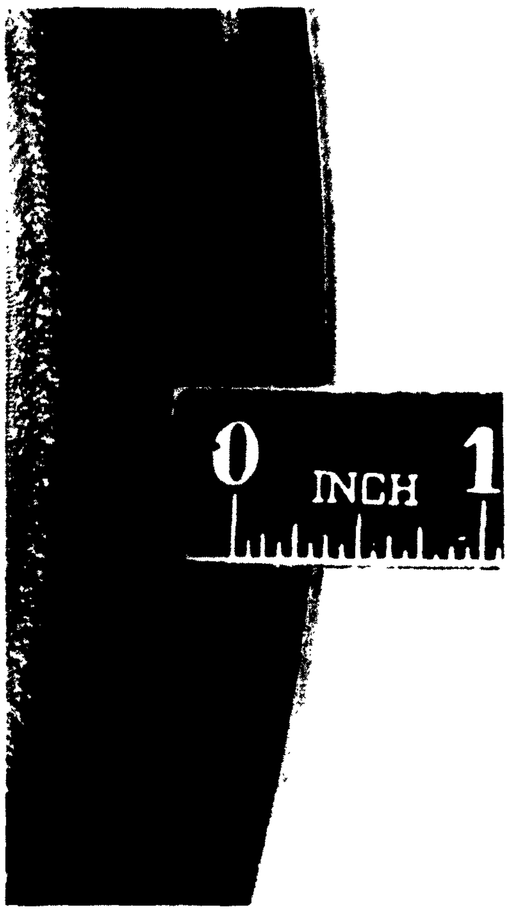
A schedule of the numerous shutdowns is given as Table IV. Although there were a number of shutdowns, none of them were because of transmission difficulties or malfunctions.

Table IV. Schedule of Test Cycle Interruptions, Transmission, Serial Number OX-164; MIL-L-2104A, OE-30, M-14804 Oil.

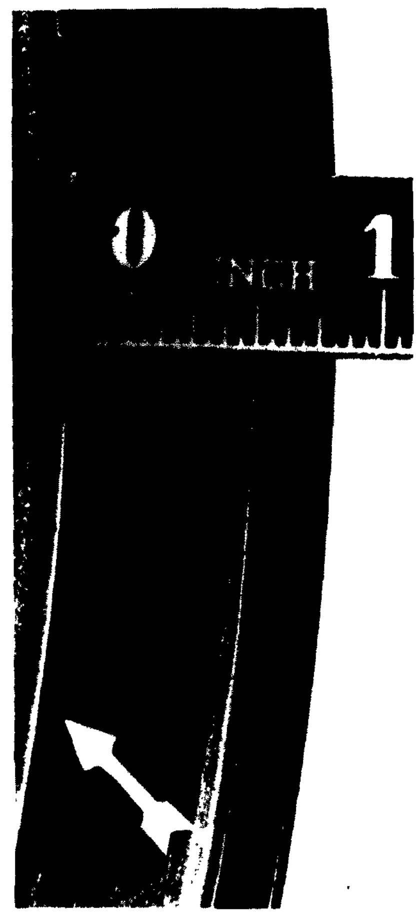
Date, 1960	Test Hours	Remarks	Down Time, hr
5 Dec	0	Start of test.	-
6 Dec	24	Scheduled 2-hour shutdown.	2
7 Dec	48	Scheduled 2-hour shutdown.	2
8 Dec	72	Scheduled 2-hour shutdown.	2
8 Dec	77	Stopped to permit electrical work in the building.	1/2
9 Dec	96	Scheduled 2-hour shutdown.	2
9 Dec	109	Shut down for weekend.	49
12 Dec	121	Stopped to renew distributor, and shut down due to weather conditions.	20
14 Dec	138	Shut down because of engine crankshaft failure.	62
16 Dec	139	Shut down to check crank-shaft end play and clean oil filter.	3
17 Dec	157	Shut down due to electric power failure.	4
18 Dec	174	Stopped to adjust and file engine breaker points.	1/2
18 Dec	184	Scheduled 2-hour shutdown.	2
19 Dec	208	Scheduled 2-hour shutdown.	2
21 Dec	240	Test completed.	

Six and one-half quarts of oil were added to the transmission during the course of the test. Four of these quarts were added to make up for oil lost when the transmission was removed and partially disassembled after the crankshaft failure. One quart was added to make up for the oil sample taken at 120 hours. During retarder application the temperature of the oil coming from the retarder reached 330°F, causing the oil to foam and spew from the filler tube. The higher viscosity of the 30W oil was in all probability responsible for the high temperatures generated in the retarder.

The over-all appearance of the transmission was good. The low sun gear showed some slight spalling near the roots of some of the teeth (Figure 2); however, it was in much better condition than the gears lubricated with OE-S and OE-10 oils in the laboratory. There were some heat-discoloration spots on the intermediate-range steel clutch plates. No such markings were found in the transmissions run with OE-S and OE-10 oils in the laboratory. The most significant failures were hardening and embrittlement of the paper valve-body gasket and breakdown of the polyacrylate piston seals. Figure 3 shows a segment of the black ring and rubber particles deposited on the cylinder wall when using OE-30 oil, compared with the normal condition when using OE-S oil.



Transmission Serial No. OX164
MIL-O-2104A, OE-30, M14804,
REO-149-61 Oil.



Transmission Serial No. OX181
MIL-O-10295, OE-S, REO-127,
Arctic Oil.

Figure 3: Cylinder-Wall Deposits Formed by Polyacrylate Piston Seals.

PERFORMANCE DURING ENDURANCE OPERATION

Transmission-Fluid Compatibility Tests

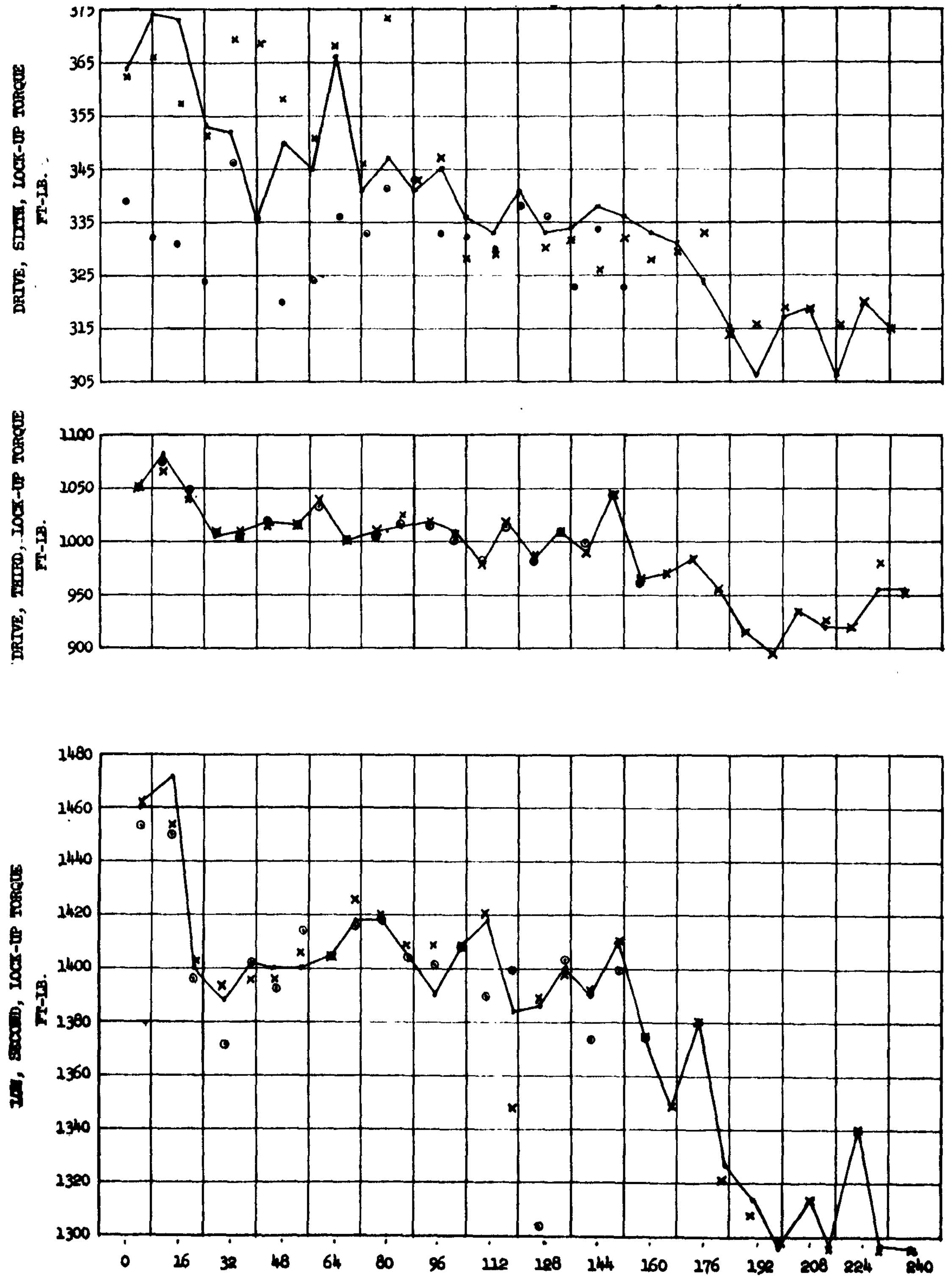
Transmission Output Torques Versus Operating Hours

Figure 4

TX-200-2X Transmission, S.N. OX-178
MIL-L-2104A, OE-10, M14500 Oil
DATES OF TEST: 25 Aug. - 19 Sept. 1960

TX-200-2X Transmission, S.N. OX-181
MIL-0-10295, OE-S, REO-127 Arctic Oil
DATES OF TEST: 31 Oct. - 9 Nov. 1960

TX-200-2X Transmission, S.N. OX-164
MIL-L-2104A, OE-30, M14804 Oil
DATES OF TEST: 5 Dec. - 21 Dec. 1960



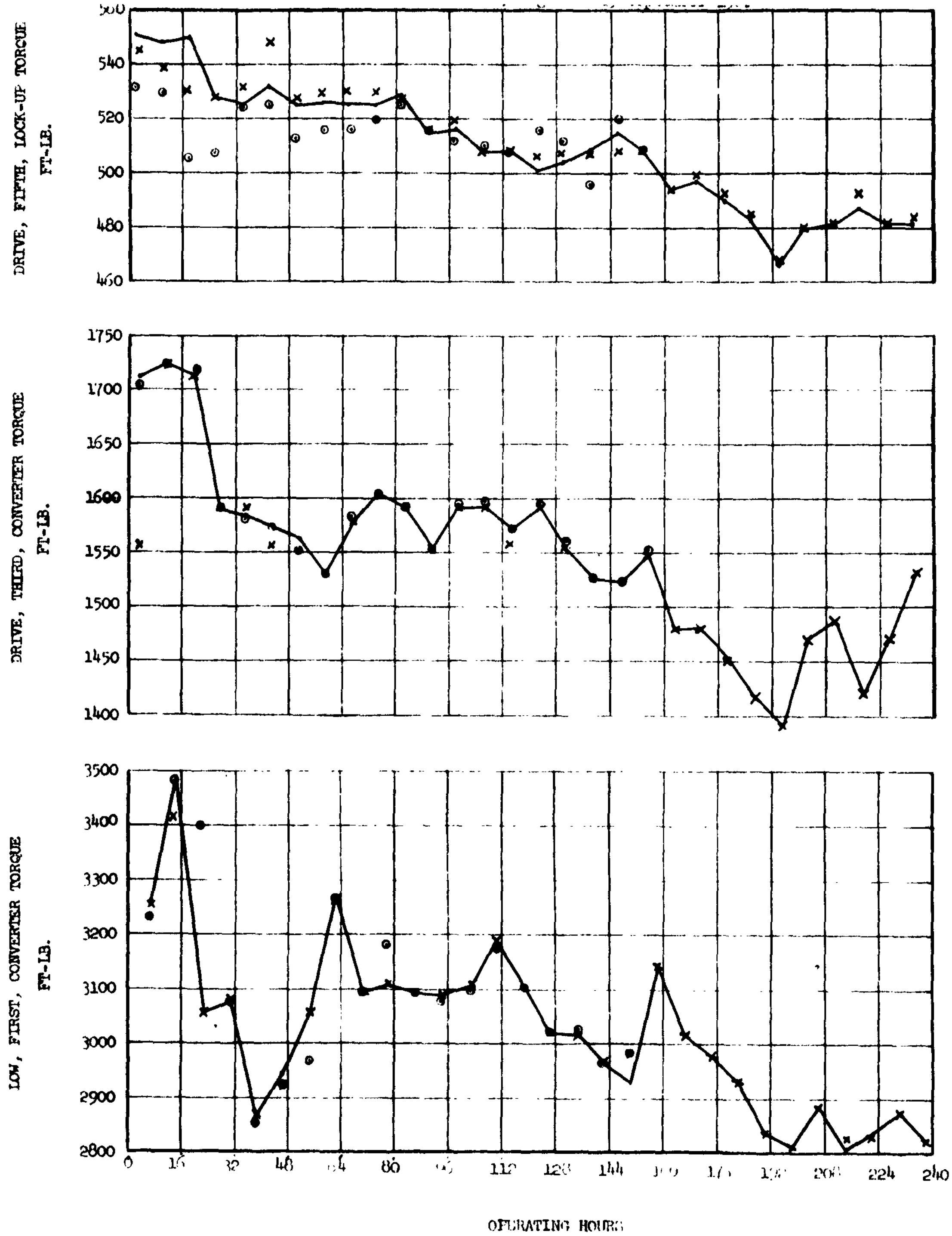
Transmission-Fluid Compatibility Tests

Transmission Output Torques Versus Operating Hours
Figure 5

TX-200-2X Transmission, S.N. OX-178
MIL-L-2104A, OE-10, M14500 Oil
DATES OF TEST: 25 Aug. - 19 Sept. 1960

TX-200-2X Transmission, S.N. OX-181
MIL-O-10295, OE-S, RXO-127 Arctic Oil
DATES OF TEST: 31 Oct. - 9 Nov. 1960

TX-200-2X Transmission, S.N. OX-164
MIL-L-2104A, OE-30, M14804 Oil
DATES OF TEST: 5 - 21 Dec. 1960



3.2.3 M35E8, 2-1/2 Ton Truck, TX-200-3X Transmission Serial Number 30821; MIL-L-2104A, OE-10, M-14500, REO-148-61 Oil. There were a number of interruptions during the 5000 miles of cross-country operation, but none of them were caused by the transmission. Considering the operation to which the transmission was subjected, its over-all appearance was good. In contradiction to the laboratory tests, the clutch plates were the most distressed areas. Figure 6 shows the worst area of wear and heating, which occurred on the intermediate-range clutch plates.

Figure 6: M35E8, 2-1/2 Ton Truck, TX-200-3X Transmission, Serial Number 30821; MIL-L-2104A, OE-10, M14500, REO-148-61 Oil. Intermediate-Range Clutch Plates.

Table V shows that the oils did not noticeably deteriorate during the course of the tests. The analyses show that although more oil was lost during the first part of the tests, most of the pentane and benzene insolubles were acquired during the first 120 hours.

Table V. Analysis of New and Used Transmission Fluids Tested.

	New Oil			After 120 Hours			At End of Test			M35E8, 2½ Ton Truck, TX-200-3X Transmission, S.N. 30821, OE-10 Oil			
	OE-10	OE-S	OE-30	OE-10	OE-S	OE-30	OE-10	OE-S	OE-30	2000 Mi.	3000 Mi.	4000 Mi.	5000 Mi.
Gravity A.P.I.	29.2	27.2	24.9	29.6	27.1	24.8	29.5	27.0	24.8	29.2	28.9	29.0	29.3
Copper Strip Corrosion 24 hr. @ 210°F	None	2C	None	None	2C	1A	None	3A	1A	None	None	None	1B
Steel Strip Corrosion 24 hr. @ 210°F	None	None	None	None	None	Pass	None	None	Pass	None	None	None	None
Pour Point - °F	-25	-75	-10	-25	-75	-10	-25	-80	-10	-20	-15	-20	-20
Carbon Residue - %	1.63	.65	1.87	1.53	.85	1.77	1.45	.91	1.95	1.39	1.41	1.45	1.42
Water - %	None	None	None	None	None	None	None	None	None	None	None	None	None
Sulphated Ash - %	1.35	.67	1.44	1.31	.86	1.35	1.29	.92	1.34	1.22	1.29	1.28	1.31
Viscosity - SSU @ 100°F	183	112	613	156.7	98	599	163.3	94	584	180.5	178	180	181
Viscosity - SSU @ 210°F	46.14	50	100	44.43	41	65	44.85	40	65.3	45.88	47	45.5	46
Viscosity Index	110	188	140	114	157	84	113	159	86	109	120	109	109
Neutrilization No. mg KOH/g Oil	.57	.01	.58	.50	.09	.52	.48	.14	.41	.39	.41	.57	.45
Pentane Insolubles	.004	.002	.002	.020	.010	.006	.025	.017	.007	.015	.34	.017	.09
Benzene Insolubles	None	None	None	.018	.003	.005	.020	.006	.005	.012	.03	.010	.06

OE - 10 MIL-L-2104A, Qualification No. M14500, RBO-148-61
OE-S MIL-O-10295, RBO-127
OE-30 MIL-L-2104A, Qualification No. M14804, RBO-149-61

Table VI summarizes the inspection team's findings (presented in full in Appendix A of this report). The over-all lowest ratings were in the areas of wear, stain and deposits. In the area of wear the splitter-output-shaft components had the lowest over-all ratings for the laboratory tests and the intermediate-range components had the lowest over-all rating for the vehicle test.

3.3 Discussion

Total failure of the low sun gear for the second time indicates that MIL-0-10295, OE-S, REO-127 oil does not have the lubricating qualities necessary to meet the referee base-line condition established by the laboratory test with MIL-L-2104A, OE-10, M-14500, REO-148-61 oil. The low sun gear which operated with OE-10 oil in the vehicle was in far better condition than the gear which operated with the same OE-10 oil in the laboratory. The low-range operation in the laboratory was possibly twice as severe as that in the field test. In the laboratory the transmission was in low range for 15% of the time with the engine at wide-open throttle, while for the field test low-range operation accounted for 9% to 12% of the time. To determine if similar failures will occur under actual operating conditions, a 5000-mile cross-country test has been proposed for the M35E8, 2-1/2 ton truck, to be run in a cold climate with MIL-0-10295, OE-S, REO-127 oil as the transmission fluid.

Hardening and embrittlement of the paper valve-body gaskets and breakdown of the polyacrylate piston seals indicated incompatibility with MIL-L-2104A, OE-30, M-14804, REO-149-61 oil in these areas. Breakdown of the piston seals with OE-30 oil is unusual because, normally, heavier oil causes less swelling and softening. It was decided by the inspection group that bench-type studies should be made to determine the cause of these failures. A standard bench-type test will be conducted by the Socony Mobil Oil Co. Laboratory. This test will consist of immersing the polyacrylate piston seals in samples of the OE-10 and OE-30 test oils for 70 hours at 300°F and checking for such things as changes in volume and hardness.

All of the laboratory tests showed very little clutch-plate distress compared with the severe wear which occurred within the intermediate-range clutch-pack during test-course operation. This was undoubtedly due to the differences in shift-cycle severity. Check runs on the Churchville test course indicated that with no trailer and on a dry course there would be a total of 85,000 shifts for 5000 miles of operation, and that with the trailer and a muddy course there would be 91,250 shifts. Averaging the data for both conditions there would be a total of 47,250 splitter shifts during the 5000-mile test. During each test in the laboratory the transmissions were shifted 2850 times, of which 2730 were full-power splitter shifts. This is only 5.8% the total number of splitter shifts experienced at Churchville.

During the first stages of TX-200 transmission testing there were very limited data on which to base a shift sequence. It was impractical to shift in a pattern duplicating field shifting and even to use all clutch sets. It was reasoned that the splitter would shift most often and might be the most

Table VI. Summary of Inspection Data

	Wear				Distortion				Heat				Stain and Deposit			
	S.N. OX-178 OE-10	S.N. OX-181 OE-S	S.N. OX-164 OE-30	S.N. 30821 OE-10	S.N. OX-178 OE-10	S.N. OX-181 OE-S	S.N. OX-164 OE-30	S.N. 30821 OE-10	S.N. OX-178 OE-10	S.N. OX-181 OE-S	S.N. OX-164 OE-30	S.N. 30821 OE-10	S.N. OX-178 OE-10	S.N. OX-181 OE-S	SN OX-164 OE-30	S.N. 30821 OE-10
Intermediate range.	100	94	99	81	100	100	100	89	100	100	97	84	88	91	92	90
Low range.	100	95	97	90	100	100	100	100	100	100	100	97	77	92	95	90
Output shaft.	97	90	95	92	100	100	100	100	100	100	100	100	90	88	93	90
Input shaft.	89	78	96	91	100	100	100	100	98	98	100	100	99	89	93	94
Low splitter.	94	89	99	90	96	100	100	100	100	100	100	100	97	91	93	90
High splitter.	93	89	92	91	100	100	100	100	100	97	100	100	100	90	91	93
High range.	98	91	100	93	100	100	100	100	100	95	100	100	96	90	89	91
Splitter output.	66	86	82	86	100	100	100	100	100	100	100	100	100	95	92	94
Converter.	90	96	96	94	96	100	100	99	97	95	99	100	99	93	96	91
Range selector.	95	100	91	92	100	100	100	100	100	97	95	99	97	83	90	95
Exhaust regulator.	100	100	87	93	100	100	100	100	100	100	100	100	100	80	82	93
Over-all average.	93	92	94	90	99	100	100	99	100	98	99	98	95	89	91	92

Rating scale:

100 = Perfect, 90 = slight, 70 = light, 50 = medium, 0 = heavy.

Serial Number OX-178, OE-10 - MIL-L-2104A, M-14500, REO-148-61 oil.
Serial Number OX-181, OE-S - MIL-O-10295, REO-127 oil.
Serial Number OX-164, OE-30 - MIL-L-2104A, M-14804, REO 149-61 oil.
Serial Number 30821, OE-10 - M35E8, 2-1/2 ton truck, TX-200-3X transmission MIL-L-2104A, OE-10, M-14500, REO-148-61 oil.

critical component. A laboratory shift sequence for the splitter clutch was established; at one point this was thought to be quite extreme. When an M35E8 truck became available, a count of shifts on the Churchville course revealed some of the above-mentioned data. While there appeared to be a large discrepancy in a direction contradictory to previous thinking, the laboratory cycle was still considered adequate because: 1) the laboratory shifts were all full-load shifts and were expected to be more severe; 2) the intention was not to duplicate 5000 miles on the Churchville course, but to include high-speed highway operation, which would reduce the number of field shifts. The complete field data obtained illustrated the shortcomings of setting up a shift cycle with insufficient information. For further transmission test programs, complete field data should be available during the first stages.

4. CONCLUSIONS

The MIL-0-10295, OE-S, REO-27 oil is incompatible with the TX-200-2X transmission with reference to the established referee base-line condition.

The MIL-L-2104A, OE-30, M-14804, REO-149-61 oil is compatible with the TX-200 transmission except for the polyacrylate piston seals.

The 240-hour laboratory test cycle used for the TX-200 transmission tests is less severe on clutch wear and more severe on low-range gearing than a 5000-mile test of the M35E8, 2-1/2 ton truck on the Churchville test course.

5. RECOMMENDATIONS

It is recommended that:

a. Bench-type tests be performed to determine the cause of breakdown of the polyacrylate piston seals with MIL-L-2104A, OE-30, M-14804, REO-149-61 oil.

b. A 5000-mile cross-country test be run in a cold climate with the M35E8, 2-1/2 ton truck and MIL-0-10295, OE-S, REO-127 oil as the transmission fluid, to determine whether or not arctic oil would cause low-sun-gear failures during actual arctic field operation.

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2. Woomert, D. E. "The Development of a Procedure for Evaluating an Automatic Transmission Fluid." Project TB5-0003/1, Engineering Laboratories Report No. 100, dated September 1959. Aberdeen Proving Ground, Maryland.

3. Kleinfeld, R. C. "Establishing a Base Line for Evaluating Transmission Fluids for the TX-200-2X Transmission." Project OCO/1-87, Report No. DPS-106, dated December 1960. Aberdeen Proving Ground, Maryland.

4. Minutes of the Inspection of the Coordinating Research Council, "Inspection of TX-200 Transmission," dated 23 March 1961.

5. Minutes of the Inspection of the Coordinating Research Council, "Inspection of TX-200-2X Transmission," dated 29 September 1960.

APPENDICES

APPENDIX A

Transmission Inspection Data Sheets

TX-200-2X TRANSMISSION INSPECTION

SERIAL NO. OX181 - OE-S, REO-127 OIL

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Intermediate Range					
Oil Collector	10	10	10	9	
Clutch Reaction Housing	9	10	10	9	
Clutch Plate (2)	9	10	10	9	
Clutch Plate Steel (1)	9	10	10	9	
Apply Plate	9	10	10	9	
Ring Gear *	9	10	10	9	
Spring	10	10	10	9	
Piston Seals (2)	10	10	10	10	Imbedded material from failure
Piston	10	10	10	9	Secondary scoring on I.D. from failure
Low Range					
Clutch Reaction Housing	9	10	10	9	
Clutch Plate (2)	9	10	10	9	
Clutch Plate Steel (1)	9	10	10	9	Not disassembled
Spring	10	10	10	9	
Piston Seals (2)	10	10	10	10	Cuts from sun gear failure
Piston	10	10	10	9	

* See intermediate planet carrier and splitter output shaft for remaining parts of gear set. All marked with *.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Reverse Range					
Clutch Reaction Housing	10	10	10	9	
Clutch Plate (2)	9	10	10	10	
Clutch Plate Steel (1)	10	10	10	10	
Apply Plate	10	10	10	9	
Spring	10	10	10	9	
Piston Seal (2)	10	10	10	10	Cuts from failure
Piston	10	10	10	9	
Sun Gear	10	10	10	9	
Thrust Washer	9	10	10	9	
Ring Gear	10	10	10	9	
Sun Gear Shaft	10	10	10	9	Teeth battered from failure
Intermediate Planet Carrier					
Planets*	9	10	10	9	
Low Ring Gear**	Failed due to sun gear failure				
Output Shaft	10	10	10	9	
Low Planets**	Failed due to sun gear failure				
Bushing	9	10	10	9	
Thrust Washer	8	10	10	8	
Rear Pitot	10	10	10	9	
Rear Oil Pump	8	10	10	9	

* See splitter output shaft and intermediate range for other parts of gear set. All marked with *.
** See splitter output shaft for other parts of gear set. All marked with **.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Input Shaft					
Seal Ring (2 Hook Type)	8	10	10	9	
Retarder Impeller ‡	10	10	10	10	
Bushing	7	10	10	9	
Thrust Washer (Needle)	9	10	10	8	
Splitter Ring Gear	5	10	10	9	
Splitter Planet Carrier	10	10	10	9	
Planets	2	10	10	9	Needle bearings failed
Thrust Washers (Bronze)	10	10	8	8	
Splitter Sun Gear	9	10	10	9	
Bore	8	10	10	9	
Low Splitter					
Clutch Reaction Plate	10	10	10	9	
Clutch Plate	8	10	10	9	
Piston	9	10	10	9	
Piston Seal (Synthetic)	7	10	10	9	Softer - evidence of abrasion
Piston Seal (H.T.)	9	10	10	9	
Diaphragm	10	10	10	10	
Bore	9	10	10	9	
Seal Rings (4 H.T.)	8	10	10	8	
Front Pitot	10	10	10	10	

‡ See Converter section for chamber

	Wear	Distortion	Heat	Stain & Deposit	Remarks
High Splitter					
Housing	5	10	10	9	Clutch tangs wore the Housing mating part
Bore	9	10	10	9	
Piston	10	10	10	9	
Piston Seal (Synthetic)	10	10	10	9	
Piston Seal (H.T.)	8	10	10	9	
Spring	10	10	10	9	
Clutch Plates (2)	9	10	10	9	
Clutch Plate Steel (1)	9	10	7	9	
Clutch Back Plate	10	10	10	9	
High Range					
Housing	10	10	10	9	
Bore	10	10	10	9	
Bushing	9	10	10	9	
Piston	8	10	10	9	
Piston Seal (Synthetic)	8	10	10	9	One chipped place
Piston Seal (H.T.)	8	10	10	9	
Spring	10	10	10	9	
Clutch Plates (4)	9*	10	7	9	
Clutch Plates Steel (3)	9	10	8	9	
Clutch Back Plate	9	10	10	9	
Power Take Off Gear	10	10	10	9	

* First plate flaked and had metal chips, other three looked good.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Splitter Output Shaft	6	10	10	9	
Seal Rings (3H.T.)	8	10	10	9	
Lube Orifice Plug	10	10	10	10	
Low Sun Gear **	0	Gear completely failed			
Intermediate Sun Gear*	9	10	10	10	
Converter					
Pump Cover	10	10	10	8	Metal deposit
Bushing	9	10	10	10	
Lock-up Piston	10	10	10	8	
Seals	10	10	10	8	
Lock-up Clutch Plate	9	10	10	10	
Lock-up Reaction Plate	10	10	10	10	
Seal (Synthetic)	10	10	10	10	Soft & no cracks
Turbine	10	10	9	10	Metal Deposit
Stator	10	10	9	10	
Thrust Faces	10	10	10	8	
Rollers	10	10	10	8	
Springs	10	10	9	8	
Roller Race	10	10	10	9	Slight roughness
Ball Bearing	10	10	10	9	
Bearing Retainer	10	10	10	9	
Pump Hub	8	10	10	8	
Seal Ring (H.T.)	10	10	10	9	Metal deposit
Pump	10	10	10	10	
Seal Ring (Synthetic)	10	10	10	10	Soft, no cracks
Housing	10	10	10	10	
Seal	10	10	10	10	
Front Oil Pump	8	10	10	8	Stain
Seal Ring (Synthetic)	10	10	10	10	Soft, no cracks

** See low ring gear and output shaft for other parts of gear set.
* See intermediate range and intermediate planet carrier for other parts of gear set.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Converter (Cont.)					
Ground Sleeve	9	10	10	10	
Bushing	7	10	10	10	
Roller Thrust Bearing	10	10	10	10	
Retarder Chamber (Both Sides)‡	10	10	10	10	
Retarder Valve Body					
Lube Regulator Valve (Ball)	10	10	10	10	
Range Selector Valve Body					
Throttle Valve	10	10	10	7	Metal particles in valve body
Range Selector Valve	10	10	10	7	
Low Intermediate Shift Valve	10	10	10	8	
Throttle Regulator Valve	10	10	10	7	
Main Pressure Regulator	10	10	10	8	
Lock-up Shift	10	10	10	7	
Valve Body Gasket	10	10	7	10	

‡ See input shaft for impeller.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Range Selector Valve Body (Cont.)					
Splitter Shift	10	10	10	9	
Splitter Relay	10	10	10	9	
Intermediate - High Shift	10	10	10	9	
Nylon Ball	10	10	10	10	
Exhaust Regulator Valve Body					
Separator Plate	10	10	10	7	
Lock-up Cut Off Valve	10	10	10	9	
Low Splitter Regulator Exhaust Valve	10	10	10	8	
Intermediate - Range Exhaust Regulator Valve	10	10	10	8	
Down Shift Timing Valve	10	10	10	8	
Oil Pan	10	10	10	7	Metal Deposits
Filter	10	10	10	8	

TX-200-2X TRANSMISSION INSPECTION

SERIAL NO. OX-164 - OE-30, M14804, REO-149-61 OIL

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Intermediate Range					
Oil Collector	10	10	10	9	
Clutch Reaction Housing	10	10	9	9	
Clutch Plate (2)	9	10	9	9	
Clutch Plate Steel (1)	10	10	9	9	
Apply Plate	10	10	9	9	
Ring Gear*	10	10	10	9	
Spring	10	10	10	9	
Piston Seals (2)	10	10	10	10	
Piston	10	10	10	10	
Low Range					
Clutch Reaction Housing	10	10	10	10	
Clutch Plate (2)	9	10	10	10	Chip went through
Clutch Plate Steel (1)	10	10	10	10	
Spring	9	10	10	9	
Piston Seals (2)	10	10	10	10	
Piston	10	10	10	8	Wipeable grey sludge

* See intermediate planet carrier and splitter output shaft for remaining parts of gear set.
All marked with*

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Reverse Range					
Clutch Reaction Housing	10	10	10	9	
Clutch Plate (2)	9	10	10	10	
Clutch Plate Steel (1)	10	10	10	10	
Apply Plate	10	10	10	9	
Spring	10	10	10	9	
Piston Seal (2)	5	10	10	7	Seal stuck to and deposited on bore. Seal incompatible with oil.
Piston	10	10	10	6	
Sun Gear	9	10	10	9	
Thrust Washer	10	10	10	10	
Ring Gear	9	10	10	9	
Sun Gear Shaft	10	10	10	9	
Intermediate Planet Carrier					
Planets*	9	10	10	9	
Low Ring Gear**	9	10	10	9	
Output Shaft	10	10	10	9	
Low Planets**	9	10	10	9	
Bushing	10	10	10	9	
Thrust Washer	9	10	10	10	
Rear Pitot	10	10	10	10	
Rear Oil Pump	9	10	10	9	

* See splitter output shaft and intermediate range for other parts of gear set. All marked with *.
** See splitter output shaft for other parts of gear set. All marked with **.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Input Shaft					Generally looks excellent
Seal Ring (2 Hook Type)	10	10	10	10	
Retarder Impeller ±	10	10	10	9	
Bushing	10	10	10	9	
Thrust Washer (Needle)	10	10	10	10	
Splitter Ring Gear	10	10	10	9	
Splitter Planet Carrier	8	10	10	9	
Planets	10	10	10	9	
Thrust Washer (Bronze)	10	10	10	9	
Splitter Sun Gear	9	10	10	9	
Bore	9	10	10	10	
Low Splitter					
Clutch Reaction Plate	10	10	10	9	
Clutch Plate	10	10	10	9	
Piston	10	10	10	9	
Piston Seal (Synthetic)	10	10	10	10	
Piston Seal (H.T.)	10	10	10	9	
Diaphragm	10	10	10	10	
Bore	9	10	10	9	
Seal Rings (4 H.T.)	10	10	10	9	
Front Pitot	10	10	10	10	

± See Converter section for chamber

	Wear	Distortion	Heat	Stain & Deposit	Remarks
High Splitter					
Housing	5	10	10	9	Clutch tangs wore the housing mating part
Bore	9	10	10	10	
Piston	10	10	10	9	
Piston Seal (Synthetic)	10	10	10	8	
Piston Seal (H.T.)	10	10	10	9	
Spring	10	10	10	9	
Clutch Plates (2)	9	10	10	9	
Clutch Plate Steel (1)	10	10	10	10	Slight wear on tangs - surface like new
Clutch Back Plate	10	10	10	9	
High Range					
Housing	10	10	10	9	
Bore	10	10	10	9	
Bushing	10	10	10	9	
Piston	10	10	10	9	
Piston Seal (Synthetic)	10	10	10	9	
Piston Seal (H.T.)	10	10	10	8	
Spring	10	10	10	9	
Clutch Plates (4)	10	10	10	9	
Clutch Plates Steel (3)	10	10	10	9	
Clutch Back Plate	10	10	10	9	
Power Take Off Gear	10	10	10	9	

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Slitter Output Shaft	7	10	10	9	
Seal Rings (3 H.T.)	8	10	10	10	
Lube Orifice Plug	10	10	10	9	
Low Sun Gear **	7	10	10	9	
Intermediate Sun Gear	9	10	10	9	
Converter					
Pump Cover	10	10	10	6	
Bushing	9	10	10	10	
Lock-up Piston	10	10	10	8	
Seals	10	10	10	10	
Lock-up Clutch Plate	9	10	10	10	
Lock-up Reaction Plate	10	10	10	10	
Seal (Synthetic)	10	10	10	10	Excellent shape
Turbine	10	10	9	10	
Stator	10	10	10	10	
Thrust Faces	10	10	9	10	
Rollers	10	10	10	10	
Springs	9	10	10	10	
Roller Race	9	10	10	9	
Ball Bearing	10	10	10	9	
Bearing Retainer	10	10	10	9	
Pump Hub	8	10	10	10	
Seal Ring (H.T.)	9	10	10	10	
Pump	10	10	10	8	
Seal Ring (Synthetic)	10	10	10	10	No cracking
Housing	10	10	10	10	
Seal	10	10	10	10	
Front Oil Pump	9	10	10	10	Normal
Seal Ring (Synthetic)	10	10	10	10	

** See low ring gear and output shaft for other parts of gear set.
* See intermediate range and intermediate planet carrier for other parts of gear set.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Converter (Cont.)					
Ground Sleeve	9	10	10	9	
Bushing	9	10	10	10	
Roller Thrust Bearing	10	10	10	10	
Retarder Chamber (Both Sides)±	10	10	10	10	
Retarder Valve Body					
Lube Regulator Valve (Ball)	10	10	10	10	
Range Selector Valve Body					
Throttle Valve	8	10	10	9	
Range Selector Valve	9	10	10	10	
Low Intermediate Shift Valve	9	10	10	9	
Throttle Regulator Valve	8	10	10	9	
Main Pressure Regulator	9	10	10	9	
Lock-up Shift	9	10	10	8	
Valve Body Gasket	10	10	5	10	Gasket brittle and hard

± See input shaft for impeller.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Range Selector Valve Body (Cont.)					
Splitter Shift	9	10	10	8	
Splitter Relay	10	10	10	9	
Intermediate - High Shift	10	10	10	10	
Nylon Ball	9	10	10	8	
Exhaust Regulator Valve Body					
Separator Plate	10	10	10	9	
Lock-up Cut Off Valve	9	10	10	8	
Low Splitter Regulator Exhaust Valve	8	10	10	8	
Intermediate - Range Exhaust Regulator Valve	8	10	10	8	
Down Shift Timing Valve	9	10	10	8	
Oil Pan	10	10	10	8	
Filter	10	10	10	8	

TX-200-3X TRANSMISSION INSPECTION

SERIAL NO. 30821 - OE-10, M14500, REO-148-61 OIL

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Intermediate Range					
Oil Collector	10	10	10	9	Wipeable sludge
Clutch Reaction Housing	9	10	8	9	
Clutch Plate (2)	3	7	7	9	
Clutch Plate Steel (1)	7	7	5	9	
Apply Plate	7	6	6	9	
Ring Gear*	9	10	10	9	
Spring	9	10	10	8	Rust
Piston Seals (2)	9	10	10	10	
Piston	10	10	10	9	
Low Range					
Clutch Reaction Housing	9	10	10	9	
Clutch Plate (2)	8	10	9	9	
Clutch Plate Steel (1)	10	10	9	9	
Spring	9	10	10	9	
Piston Seals (2)	8	10	10	9	
Piston	10	10	10	9	

* See intermediate planet carrier and splitter output shaft for remaining parts of gear set. All marked with *.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Reverse Range					
Clutch Reaction Housing	9	10	9	9	
Clutch Plate (2)	9	10	7	9	
Clutch Plate Steel (1)	9	10	7	9	
Apply Plate	9	10	9	9	
Spring	9	10	10	9	
Piston Seal (2)	9	10	10	9	
Piston	10	10	10	9	
Sun Gear	8	10	10	9	
Thrust Washer	9	10	10	9	
Ring Gear	9	10	10	9	
Sun Gear Shaft	10	10	10	9	
Intermediate Planet Carrier					
Planets*	9	10	10	9	
Low Ring Gear**	9	10	10	9	
Output Shaft	10	10	10	9	
Low Planets**	9	10	10	9	
Bushing	9	10	10	9	
Thrust Washer	9	10	10	9	
Rear Pitot	10	10	10	9	
Rear Oil Pump	8	10	10	9	

* See splitter output shaft and intermediate range for other parts of gear set. All marked with *.
** See splitter output shaft for other parts of gear set. All marked with **.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Input Shaft					
Seal Ring (2 Hook Type	9	10	10	10	
Retarder Impeller ‡	10	10	10	10	
Bushing	10	10	10	9	
Thrust Washer (Needle)	10	10	10	10	
Splitter Ring Gear	6	10	10	9	
Splitter Planet Carrier	10	10	10	9	
Planets	10	10	10	9	
Thrust Washer (Bronze)	7	10	10	9	
Splitter Sun Gear	10	10	10	9	
Bore	9	10	10	10	
Low Splitter					
Clutch Reaction Plate	10	10	10	9	
Clutch Plate	10	10	10	9	
Piston	5	10	10	9	
Piston Seal (Synthetic)	8	10	10	10	
Piston Seal (H.T.)	10	10	10	10	
Diaphragm	10	10	10	9	
Bore	10	10	10	9	
Seal Rings (4 H.T.)	8	10	10	8	
Front Pitot	10	10	10	10	

‡ See Converter section for chamber.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
High Splitter					
Housing	9	10	10	10	No seal stain
Bore	9	10	10	10	
Piston	9	10	10	9	
Piston Seal (Synthetic)	9	10	10	9	
Piston Seal (H.T.)	9	10	10	10	
Spring	10	10	10	9	
Clutch Plates (2)	9	10	10	9	
Clutch Plate Steel (1)	9	10	10	9	
Clutch Back Plate	9	10	10	9	Slight rust on non-wear side
High Range					
Housing	9	10	10	9	
Bore	9	10	10	9	
Bushing	8	10	10	9	
Piston	10	10	10	9	
Piston Seal (Synthetic)	10	10	10	10	
Piston Seal (H.T.)	9	10	10	9	
Spring	10	10	10	9	
Clutch Plates (4)	9	10	10	9	
Clutch Back Plate	9	10	10	9	
Power Take Off Gear	10	10	10	9	

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Splitter Output Shaft	8	10	10	9	
Seal Rings (3H.T.)	7	10	10	10	
Lube Orifice Plug	10	10	10	10	
Low Sun Gear **	9	10	10	9	
Intermediate Sun Gear*	9	10	10	9	
Converter					
Pump Cover	10	10	10	7	
Bushing	9	10	10	9	
Lock-up Piston	9	10	10	9	
Seals	9	9	10	9	
Lock-up Clutch Plate	9	10	10	9	
Lock-up Reaction Plate	8	10	10	9	
Seal (Synthetic)	10	10	10	10	
Turbine	10	10	10	10	
Stator	9	10	10	9	
Thrust Faces	9	10	10	9	
Rollers	10	10	10	9	
Springs	9	10	10	9	
Roller Race	10	10	10	9	
Ball Bearing	10	10	10	9	
Bearing Retainer	10	10	10	9	
Pump Hub	10	10	10	10	
Seal Ring (H.T.)	10	10	10	10	
Pump	9	10	10	9	
Seal Ring (Synthetic)	10	10	10	9	
Housing	10	10	10	10	
Seal	9	10	10	9	
Front Oil Pump	9	10	10	9	
Seal Ring (Synthetic)	10	10	10	9	

** See low ring gear and output shaft for other parts of gear set.
* See intermediate range and intermediate planet carrier for other parts of gear set.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Converter (Cont.)					
Ground Sleeve	9	10	10	9	
Bushing	9	10	10	9	
Roller Thrust Bearing	9	10	10	9	
Retarder Chamber (Both Sides) ±	10	10	10	9	
Retarder Valve Body	10	10	10	9	
Lube Regulator Valve (Ball)	10	10	10	9	
Range Selector Valve Body					
Throttle Valve	9	10	10	9	
Range Selector Valve	9	10	10	9	
Low Intermediate Shift Valve	9	10	10	10	
Throttle Regulator Valve	9	10	10	9	
Main Pressure Regulator	9	10	10	9	
Lock-up Shift	9	10	10	9	
Valve Body Gasket	10	10	9	10	

± See input shaft for impeller.

	Wear	Distortion	Heat	Stain & Deposit	Remarks
Range Selector Valve Body (Cont.)					
Splitter Shift	9	10	10	10	
Splitter Relay	9	10	10	10	
Intermediate - High Shift	9	10	10	10	
Nylon Ball	10	10	10	10	
Exhaust Regulator Valve Body					
Separator Plate	10	10	10	8	
Lock-up Cut Off Valve	9	10	10	10	
Low Splitter Regulator Exhaust Valve	9	10	10	10	
Intermediate - Range Exhaust Regulator Valve	9	10	10	10	
Down Shift Timing Valve	9	10	10	10	
Oil Pan	10	10	10	8	
Filter	10	10	10	9	

APPENDIX B

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OMS 5010.11.802
Unclassified Report

The objectives of the tests covered in this report were to evaluate MIL-O-10295, OE-S arctic engine oil and MIL-L-2104A, OE-30 engine oil as automatic transmission fluids and to compare the results of the laboratory tests with actual cross-country test-course operation. These tests showed that with reference to the established base line, MIL-O-10295, OE-S, REO-127 oil is incompatible. The MIL-L-2104A, OE-30, M14804 oil was compatible with the transmission except for breakdown of the polyacrylate piston seals.

(Cont'd reverse)

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(Cont'd reverse)

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